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New Directions in Training Simulation Research: Generating, Handling, and Delivering Empirically Based Decision Support

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Training and Simulation Technical Area
Training Research Laboratory

U. S. Army

Research Institute for the Behavioral and Social Sciences

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This paper provides an overview of recently completed, ongoing, and planned research designed to provide empirically based decision support for training device and training system design. The paper is organized into two main sections: (1) generating new empirical data on training device design and use, and (2) handling data and delivering empirically based decision support.

Research Report 1389

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Training and Simulation

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FOREWORD

The Training and Simulation Technical Area (Simulation Systems Design Team) of the Army Research Institute for the Behavioral and Social Sciences (ARI) performs research and development in areas that include training simulation with applicability to military training. Of special interest is research in the area of training device design and use requirements. Adequate decision support for determining these training system designs is not currently available.

This report provides an overview of recently completed and planned research efforts designed to provide training system design decision support. It may be used by research program planners to help coordinate future efforts in this area.

Edgar M. Johnson

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Technical Director

NEW DIRECTIONS IN TRAINING SIMULATION RESEARCH: GENERATING, HANDLING, AND DELIVERING EMPIRICALLY BASED DECISION SUPPORT

EXECUTIVE SUMMARY

Requirements:

To provide an overview of recently completed, ongoing, and planned research to develop a decision support system for the Army Training Community. Such a system should provide empirically based guidance on the design and use of training devices and simulators.

Procedure:

The paper is organized into two main sections which describe: (1) the generation of new empirical data on training device design and use and (2) how these data will be handled to provide decision support. Each of these sections is further subdivided to describe specific research efforts.

Findings:

New empirical data on training device design and use are being generated with increasing frequency. A method for organizing these data and delivering empirically based decision support is being developed. The method involves the use of data base and expert system techniques.

Utilization of Findings:

This report may be used by researchers in planning for research on training system issues and will facilitate coordination of these future research efforts. It does this by providing a brief overview of recently completed, ongoing, and planned research on training device design and use.

NEW DIRECTIONS IN TRAINING SIMULATION RESEARCH: GENERATING, HANDLING, AND DELIVERING EMPIRICALLY BASED DECISION SUPPORT

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NEW DIRECTIONS IN TRAINING SIMULATION RESEARCH: GENERATING, HANDLING, AND DELIVERING EMPIRICALLY BASED DECISION SUPPORT[1]

Introduction

The training device research program of the Army Research Institute (ARI) Training and Simulation Technical Area seeks to provide empirically based guidance for choosing the appropriate training device configuration and training method for specific Army training applications. In these applications the appropriate training method may require the use of a training device, some other type of training simulation, or no simulation at all. It is our belief that the most cost and training effective training program may be designed if well established psychological rules are used in conjunction with empirically derived training methods and training device designs. It is also our belief that empirical data may only provide useful guidance if it is available in a form tnat is both well organized and accessible to the Army training community.

The purpose of this paper is to describe the recently completed, ongoing, and planned efforts to generate, handle, and deliver empirically based training design guidance. This portion of our training device research program is therefore divided into two main thrusts: (1) the development of empirical data on training device design and use, and (2) the organization of these data into an accessible and useable form as decision support.

The amount of technical information about training methods is increasing every day. Most of this information is found in journal articles, technical reports, and handbooks that are not easily available to training design decision makers. Computers allow us to acquire, distribute, and manipulate both old and new information in ways never before possible. While computers help, the organization of information into useable knowledge requires time and training. As a result, a bottleneck exists between the technology that handles information and the humans who organize that information into useable knowledge, or use that information in the application of knowledge to a specific problem domain. The problem domain in our research program is training and simulation.

Training simulation may refer to a wide variety of training methods. Kinkade and Wheaton (1972) define a training device as "any arrangement of equipment, apparatus, or materials which provides conditions that help trainees learn a task." Furthermore, "training devices include two dimensional displays (i.e., textual, symbolic, or pictorial material) and real or simulated three-dimensional apparatus" (Kinkade and Wheaton, 1972, p. 670). It is our view that all training devices are simulations but not all simulations are used exclusively for training (see figure 1). The word simulation refers to "the imitative representation of the functioning of one system or process by means of another" (Webster's New Collegiate Dictionary, 1979).

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[1]Major portions of this paper were presented at the Fifth Interservice/Industry Training Equipment Conference, Washington, D.C., November 14-16, 1983.

According to this broad definition of simulation there can be many varieties of simulations besides those used for training purposes. Simulations may be used for engineering analysis, as in the case where a wind tunnel and a reduced size model is used to design aircraft or automobiles. Computer simulations are used to forecast the effects of various changes in the economy. Training simulation is another use of imitative representation. In this case, the desired behavior to be trained can be simulated in the classroom and students may gain experience before they must deal with real world constraints. These training simulations may or may not use training devices.

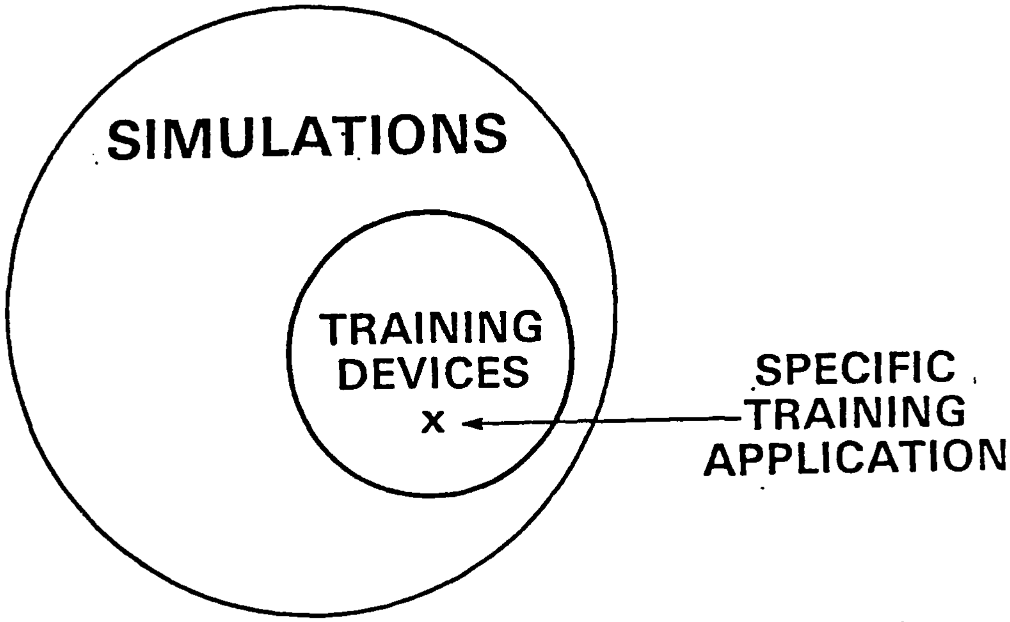

Figure 1. The relationship of training devices and simulations.

Figure 1 is a graphic representation of our view of the relationship of training devices and simulations. In this view, training devices are a subset of all possible types of simulations. Within the subset of all training devices, a specific training application may require a unique training device. There are many factors that enter into the decisions about the specification of training device characteristics. Some general information about a few gross factors and instructional features that may be used in training device applications is provided in the Appendix.

The rest of this paper is organized into two main sections, each dealing with a specific focus of our portion of the research program. The first section describes ongoing and planned research designed to provide data which answer fundamental questions about training device design and use. The second section of the paper discusses ongoing and planned efforts to organize and interpret empirical data, and deliver empirically based decision support.

Generating New Empirical Data

A major portion of our simulation research program has centered on field and laboratory research. This section provides a brief description of these research efforts. The multiyear field research effort described in this section consisted of experimental and analytical evaluations of training device concepts. The evaluations were conducted in support of the Army Maintenance Training and Evaluation Simulation System (AMTESS) program. The laboratory research described in this section consists of planned research using the training devices built during the earlier phases of the AMTESS program, and the ongoing basic research in simulator fidelity. Since efforts in both the field and the laboratory are part of the AMTESS program, a brief description of the AMTESS program is provided next.

The Army's Project Manager for Training Devices (PM TRADE) initiated the AMTESS program in 1978. PM TRADE has been the lead agency and has been supported by a Joint Working Group (JWG) consisting of representatives from ARI, Training and Doctrine Command (TRADOC), Army Schools, and other Army agencies. ARI's role in the JWG was to provide technical expertise on training effectiveness assessment and front end analysis of the AMTESS devices. ARI also conducted human factors assessments of the AMTESS devices, analytic studies of the device procurement process, and developed plans to conduct laboratory experiments using the AMTESS devices.

The three main objectives of AMTESS are to provide the Army with:

1) A hardware model for development of generic, modular maintenance trainers. These trainers would consist of a generic core module (instructor and student stations and controlling micro computer) and a task specific 3D module for hands-on practice.

2) Front end analysis procedures which would provide guidance for conducting task, training and fidelity requirements analyses.

3) Guidance for the broad application of AMTESS concepts.

The first phase of the AMTESS evaluation consisted of: a training effectiveness assessment (TEA), a cost analysis, an analysis of authoring capabilities of the AMTESS device and an engineering analysis. ARI's major role was to conduct the TEA. The objectives of this assessment were to: develop insights into effective device design, develop specifications for the AMTESS hardware model, and to develop a model for device acquisition.

that can be applied to generate very specific recommendations in that domain (e.g., the design of a specific training devices). We are using these expert system techniques to develop the prototype training device design decision support system.

Decison Support. In our expert system, now in development, user input and internally stored information about the types of tasks to be trained is combined by the system to generate a set of recommendations. The system does this by questioning the user about the types of task to be trained and extracts information from the user, (in the future it should also be able to extract information from other computer files). These questions are about the kind of training format that should be followed, or some of the kinds of features that should be incorporated in the training device in order to fit the training program. The system rules use this information to create new information about the training needs, or the adjunct features required to provide adequate support by the training device. The generation of these recommendations is based on the structured knowledge in the data base that provided the rules of the expert system. Therefore the system provides an information addition based on previously established knowledge, and provides guidance or training device design recommendations.

This ongoing research effort is something more than a decision support and data base effort. The organized information, which is empirically based information from reported research, provides a structured approach to training device design and use. This knowledge of structured relations among the various factors, as represented by the rules written into the expert system, can also be used to guide future research in simulation issues. When the system is used, each application becomes an opportunity to collect more data about the training effectiveness of the simulator and the training program. For example, when the system recommends some specific level of fidelity and amount of practice in training a task some level of proficiency is expected to develop. If the level of proficiency is much higher or much lower than expected, a deficiency is identified in either the implementation or the system recommendation. If the deficiency is in the decision system, research would be indicated on the complex interaction of factors that produced the unexpected level of proficiency. In this way the development and use of this expert system can do more than provide information and recommendations about training device design and use to the training device developer.

An added benefit is that while building the system we are also defining the gaps in our knowledge about training device design and use. To a large extent there are no general experts in training device design, and thus the expertise that we will call upon is application specific. As an example, we consult an expert in deisel mechanic training about a diesel mechanic training device. Our task is to use the knowledge of the specialist to create general rules for use in many different training device designs and applications. In addition, much of the research that nomenclature). Our goal is to develop decision support rules based on these general conclusions rather than rules based on a single research effort.

Delphi Analysis. Delphi analysis (Linstone & Turoff, 1975) is another technique that we expect to use extensively in extracting knowledge for the decision support system from the data base. It is a semi-structured procedure in which subject matter experts collaborate to achieve consensus on an issue. In our situation we will use in-house expertise to extract, review, and evaluate the verbal information in the data base (e.g., abstract, reviewers comments, etc.). The goal will be to develop a rule that accurately states the relation between a task or training parameter, a training device factor, and other training system factors. The experts will sort through the data base for related articles and then meet several times to evaluate those articles. At some point a consensus about the knowledge contained in those articles will be reduced to rule form for inclusion in the decision support system.

Structured Interviews. Structured interviews of trainers and training device developers will also be used to acquire relevant knowledge for the decision support system. We plan to adapt versions of the structured interview format used in Criswell, et. al., (1983) and Woelfel, et. al. (1984) as a starting point in this process. The general plan at this time is to present prospective users with the demonstration system and obtain their evaluations of the recommendations produced. The trainers and training developers will use their actual training situations as input to the the system. The judged differences between the system recommendations and what the trainers and training developers consider to be optimal will hopefully lead to new and improved rules for use in the system. Also their feedback about the decision support systems operation should be useful in improving the system's user interface.

Delivering the Information

Usually when information is organized to provide guidance to a specialist it is produced in the format of a guidebook. As mentioned before computers are allowing new solutions to old problems and we are developing new methods for providing guidance, using new techniques. The techniques are generally called expert systems, and are a branch or subset of Artifical Intelligence research. The decision support system acquires information from the user and combines this information with that already contained in the system to generate recommendations.

Artificial Intelligence. Artificial Intelligence refers to methodologies based in the study of human information handling patterns. The approach we are using is a subset called expert system techniques. This involves organizing information in heuristics (Smith, 1983) which are formal rules in a computer program. These rules represent general knowledge about a problem domain (in our situation, simulators and training) to 1982. The reports and articles were selected on the basis of their relevance to simulator design, simulator evaluation, and simulator effectiveness in training. Plans are currently being developed to restucture the data of text files into a more usable on-line data base format. In general the major points described above and some of the sub items will be used as records in the data base. The data base can then be used in conjunction with various techniques to extract and organize the knowledge for use in decision support system and provide user support for the decision system.

In order for the organized information in the data base to be useful to the decision support system user, it must be easy to access the empirical referents which support the explicit recommendations that the system generates. Our scenario assumes that there may be some topic on which the user wants additional information about the generated recommendation that is a result of several rule applications in the decision system (for example, the short summary of an article that is the basis of a rule in the decision system). The system of heuristics or rules used in the decision support system will be referenced to specific authors, keywords, subject matter expert opinions, and articles. In this way the user can directly consult the source from which the rule (see below) was drawn for the recommendation. In other words, the user of the decision support system can evaluate the generated recommendation by looking at the empirical information that supports the decision system.

Using the Information

We are investigating several methodologies for organizing and restructuring the information for use in the decision support system. Each methodology has strengths and weaknesses, and we are applying three techniques to ensure against loss of important knowledge. These methodologies are going to be used to extract and organize knowledge about the relationships and factors involved in the design of training devices and their use in training programs. One methodology we plan to use is meta-analysis, which will draw on key statistical data in the data base. A second methodology we plan to apply will be a delphi process which will draw on the information in the abstract, the short summary, and the commentary in the data base. A third methodology we plan to use consists of structured interviews of trainers and training developers that draws upon their expertise to generate information not available in the literature.

Meta-Analysis. Meta-analysis is a general type of statistical analysis that treats individual experiments as pieces of data in a single experiment. The summary data from each experiment are used to determine the overall effect size of the major factors concerned in all of the experiments (Glass, McGraw, & Smith, 1981). This type of analysis is used to arrive at general conclusions about the relationships among various factors (e.g., computer assisted instruction and retention of with these task parameters (e.g., instructor-student ratio, type of instructional strategies, etc.). Also, in order to evaluate the effectiveness of the training that has been provided, proficiency in the trained task must somehow be measured. How to relate this proficiency measurement to overall Army force readiness is not at all clear. However, without some kind of relevant task performance measure there is no way to compare the outcome of different training programs, or make comparisons within a single training program using different kinds of training equipment. All of these points must be considered in the delivery of decision support.

Our initial effort is descriptive and primarily serves to identify and use knowledge about training factors and relationships from existing guidance documents (e.g., Kinkade & Wheaton, 1972). The effort is also allowing us to evaluate these factors and relationships in terms of importance in describing and predicting simulation based training program effectiveness. In addition this assessment allows the identification of research areas that can provide information that would improve Army training. When research on these issues produces new empirical data they will be entered into the data base on training information that is discussed next.

Data Base On Training Device Information. In identifying and organizing the training device factors we must be sure that existing knowledge is not overlooked. Therefore, we have initiated a data base effort that we expect to develop into an applied research support tool (Hays & Singer, 1983) and which will provide the empirical foundation for a decision support system for training device design and use.

The data base currently consists of text files containing data from applications oriented research in simulator fidelity and training effectiveness issues. The information is condensed from the empirical reports and journal articles through the use of a structured and extensively annotated abstract format (Ayres, Hays, Singer & Heinicke, 1984). The files also contain information from theoretical reports that have been abstracted in the same way. Each abstract is organized according to the same 9-point format, under the following headings: (1) Authors; (2) Title; (3) Source; (4) Topic Keyword; (5) Short Summary; (6) Devices discussed or studied (7) Institution; (8) Type of Article; and (9) Abstract. These 9 headings are further broken down into subheadings and filled in with appropriate information (e.g., type of device, subject characteristics, key data, etc.) if available in the original document. We will be extending the data base by reviewing and adding information from more recent relevant reports and articles. The current version of the data base contains 149 annotated abstracts spanning a time frame from 1953

Handling Empirical Data and Delivering Empirically Based Decision Support

The data generation efforts discussed in the previous section are providing large amounts of data. Those efforts are one example of the increase in research into training and simulation issues. In addition a substantial body of information has been accumulated in the literature in recent years (see Ayres, Hays, Singer & Heinicke, 1984). At the Army Research Institute, our team has begun to study how to organize and handle the vast and growing amount of training and simulation information (Hays & Singer, 1983). Our goal is to demonstrate the feasibility of providing empirically based training device requirements decision support to Army training and procurement personnel.

In order to provide useful decision support for the Army training community, three stages are necessary. First, a structured approach for selecting and organizing appropriate research data and information from the literature is required. Second, techniques for using the information in developing decision rules or guidance must be applied. Third, an adequate means for delivering the decision support to the user must be developed.

Organizing the Information

The exponential growth of information, combined with the ever increasing technology, has out-stripped our normal methods of developing experts. The overload is exacerbated by the vast range of information sources that must be monitored in order to maintain expertise in training and simulation. The training developer doesn't have the time to continually sort through the huge volume of information generated, integrate that information into knowledge and all while still performing normal duties. As a result, training developers have a difficult task in specifying simulators. In addition, it is not easy to determine the optimal integration of simulators into training programs. Our approach is to first identify and organize the various factors involving simulators and training devices and their use in training programs (Hays & Singer, 1983). Once the issues have been identified and organized the empirical data on those issues must be accumulated in a data base. The data base then provides the empirical justification for the rules and recommendations in a decision support system.

Training Device Factors in Training Programs. One major set of factors and relations that we are addressing in the development of decision support are the task parameters in the training program. The to-be-trained tasks provide one important initial decision constraint on whether to use a training device, what the training device should be like, and how to use that training device to best effect. There are additional factors and relationships in the training context itself that interact

The experiments offer a unique opportunity to generate programmatic data on fidelity effects. They are supported by a generic device specifically constructed for this effort. The device consists of a series of electro-mechanical relays which control a set of output devices (e.g., pumps, lights, TV monitor, etc.) and into which malfunctions may be inserted. Several degraded simulators of the generic device have also been constructed and will serve as instruments for training subjects in one of the nine cells of the matrix in Figure 5. These experiments will be completed during the summer of 1985.

Summary of Data Generation Efforts. This major portion of ARI's simulation research program is generating new empirical data that can support guidance for the Army training community. The sources of these are: 1) the AMTESS field evaluations, 2) the AMTESS analytical research, 3) the planned AMTESS laboratory research program, and 4) the basic research program on simulator fidelity. The generation of these new empirical data create a new problem: how to handle the large amounts of information in an efficient and useful manner. The next section discusses new methods for dealing with this information in order to provide useful decision support.

PHYSICAL SIMILARITY

FUNCTIONAL SIMILARITY	LOW	MEDIUM	HIGH
HIGH	HL	HM	HH
MEDIUM	ML	MM	MH
LOW	LL	LM	LH

Figure 5. Nine cell matrix for training simulator fidelity experiments.

Table 2

Variables Which Interact with Fidelity

Task Type
- Operations
- Maintenance
- Others

Task Difficulty

Specific Skills Required by Task
- Motor
- Perceptual
- Cognitive
- Others

Trainee Sophistication
- Novice
- Intermediate
- Expert

Stage of Training
- Introduction
- Procedural Training
- Familiarization Training
- Skill Training
- Transition Training

Training Context
- Institutional
- Field

Incorporation of Device into POI

User Acceptance
- Instructors
- Students

Use of Instructional Features

Planned AMTESS Laboratory Research. Although large amounts of qualitative, quantitative, and analytic data have been generated from field studies of the AMTESS devices, many questions still remain unanswered. In order to determine the training effectiveness of specific device features, we need to conduct better controlled experiments. With this goal in mind, ARI and PM TRADE have moved the AMTESS breadboards to George Mason University (GMU). Experiments at GMU will focus on the training effects of several training system variables including: task type, trainee characteristics, instructional strategies, and specific training device features. These experiments will be conducted by private contractors, by GMU faculty and students, and by ARI personnel. They are expected to provide data which can be used as guidance for training device developers and instructional designers.

Simulator Fidelity Research. The degree to which a training device or simulator resembles the operational equipment is referred to as simulator fidelity. For many years, researchers have attempted to determine the optimal level of fidelity for cost effective training. ARI has established a research program to systematically accumulate the data needed to make fidelity tradeoff decisions.

The first step in this effort was to develop a consistent and useful definition of simulator fidelity. After a review of the literature (Hays, 1980) and a fidelity workshop which brought together researchers from academia, industry and the government (Hays, 1981), the following definition of simulator fidelity was adopted to guide the research program.

> Training Simulator Fidelity is the degree of similarity between the training simulator and the equipment which is simulated. It is a two dimensional measurement of this similarity in terms of:
>
> - the physical characteristics of the training simulator
>
> - the functional characteristics (i.e., the informational or stimulus and response options) of the simulated equipment (Hays, 1981, p. 70).

This definition was then implemented in a basic experimental design for exploratory research on simulator fidelity. Figure 5 shows a nine cell matrix incorporating three ordinal levels of each fidelity dimension. The first experiment to use this design investigated the effects of simulator fidelity for a mechanical adjustment task. The rationale for this experiment is reported in Baum, et al., (1982a) and the results of the experiment are reported in Baum, et al., (1982b).

A second, more ambitious effort is currently underway. It consists of a series of fidelity experiments dealing with an electro-mechanical troubleshooting task. A description of this effort is provided by Allen and Hays (1983). The first experiment in this series will look solely at the fidelity variable. Subsequent experiments will begin investigations of variables believed to interact with fidelity to produce different levels of training effectiveness. Table 2 provides a list of some of these suspected interactive variables.

malfunctions that would damage real equipment in the automotive mode). However, respondents criticized the low reliability of the simulators and the inappropriate fidelity levels for certain tasks. For certain tasks the fidelity level was regarded as too low because critical components were not included in the simulators. On the other hand, for other tasks the fidelity level was regarded as too high for familiarization training. Future simulator designers will either have to make fidelity-task type tradeoffs to insure the most training effective overall fidelity level or incorporate modules with increasing levels of fidelity as specific task training requires them. Additional research is needed to provide more detailed specifications for these fidelity decisions. The results of both the quantitative and qualitative evaluations are documented in Unger, et al., 1984 (3 Volumes).

AMTESS Analytical Research. Other analytic efforts have been undertaken to provide additional data on the AMTESS devices and the AMTESS program. Criswell, et. al., (1983) documented the history of the AMTESS program and collected opinion data on specific features of the AMTESS devices. The AMTESS history highlighted several problems which arose during AMTESS device development, acquisition and testing. Most of these problems centered on the need for (1) more frequent, more precise communications, (2) clearer definitions of the explicit responsibilities of each agency, both governement and contractor, (3) more explicit mechanisms for quality control of the devices, (4) greater anticipation of disruptive contingencies, and (5) the need for high-level administrative and financial resources appropriate to the responsibilities imposed on program personnel. Interviewers felt that many device features were based on sound instructional concepts. Implementation problems, however, especially disrepair, plagued both devices. Some of the most valued features of the devices were their high fidelity 3D modules and the comprehensive student performance records. The opinion data on device features will be valuable to future device designers and the accumulation of "lessons learned" during the AMTESS project can help in planning future efforts like AMTESS.

Woelfel, et al.,(1984) evaluated the front-end analysis (FEA) procedures used by the AMTESS hardware contractors and by the government during the early phases of the project. They cataloged and evaluated the FEA procedures used in the AMTESS project and recommended FEA guidelines to facilitate future FEA activities in AMTESS type programs. The review of FEA activities was guided by four criteria: (1) comprehensiveness of performance, (2) clarity of requirements, (3) effectiveness of coordination, and (4) reliability and maintainability (RAM) analysis, (5) organization analysis, (6) human factors analysis, and (7) person analysis.

Laboratory Research

In addition to the field research described above, several planned or ongoing laboratory research projects will provide additional empirical data on training device design and use. One of these efforts involves the planned use of the AMTESS devices. The second effort is an ongoing basic research program on the question of simulator fidelity.

A summary of the results of the evaluation of the electronics mode of the Seville/Burtek device is presented in Figure 4. For these electronics tasks, almost 70% of the comparisons between Seville/Burtek and conventionally trained groups showed no performance differences. Conventionally trained students did perform several tasks faster than simulator trained students but on a small number of tasks simulator trained student performance exceeded that of conventionally trained students.

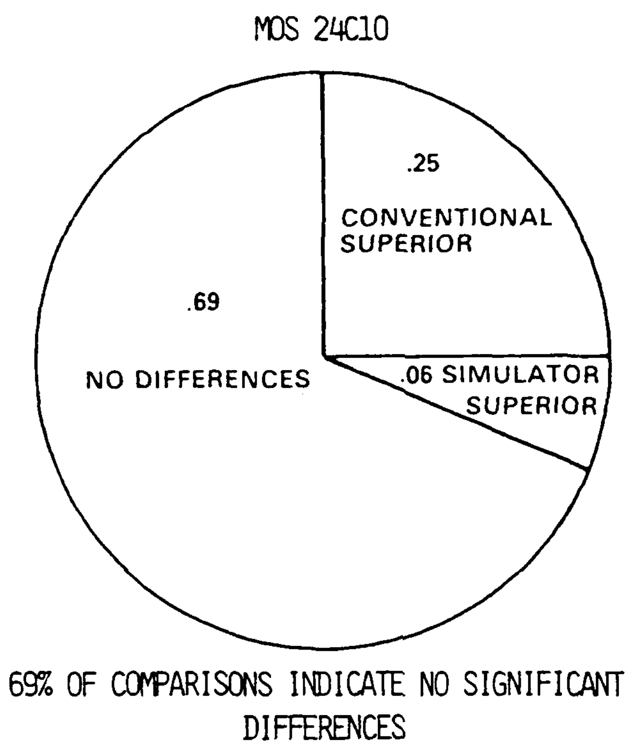

Figure 4. Summary of comparisons of conventional training to training with the Seville/Burtek device, Ft. Bliss, Texas.

As mentioned above, it was not possible to obtain a comparable conventionally trained group to use in evaluating the Grumman device in its electronics mode. Ten subjects were trained on the device, however, and were able to perform the same electronics maintenance tasks as those trained on the Seville/Burtek device. In fact, no differences in performance could be found between groups trained on either version of AMTESS in the electronics mode when tested on the actual equipment.

Opinions of instructors, course developers, and students about the AMTESS devices were also collected during the evaluations. These opinions were mostly positive. The devices were viewed as useful training media especially for tasks which could not be trained on the operational equipment (e.g., high voltage troubleshooting in the electronics mode or

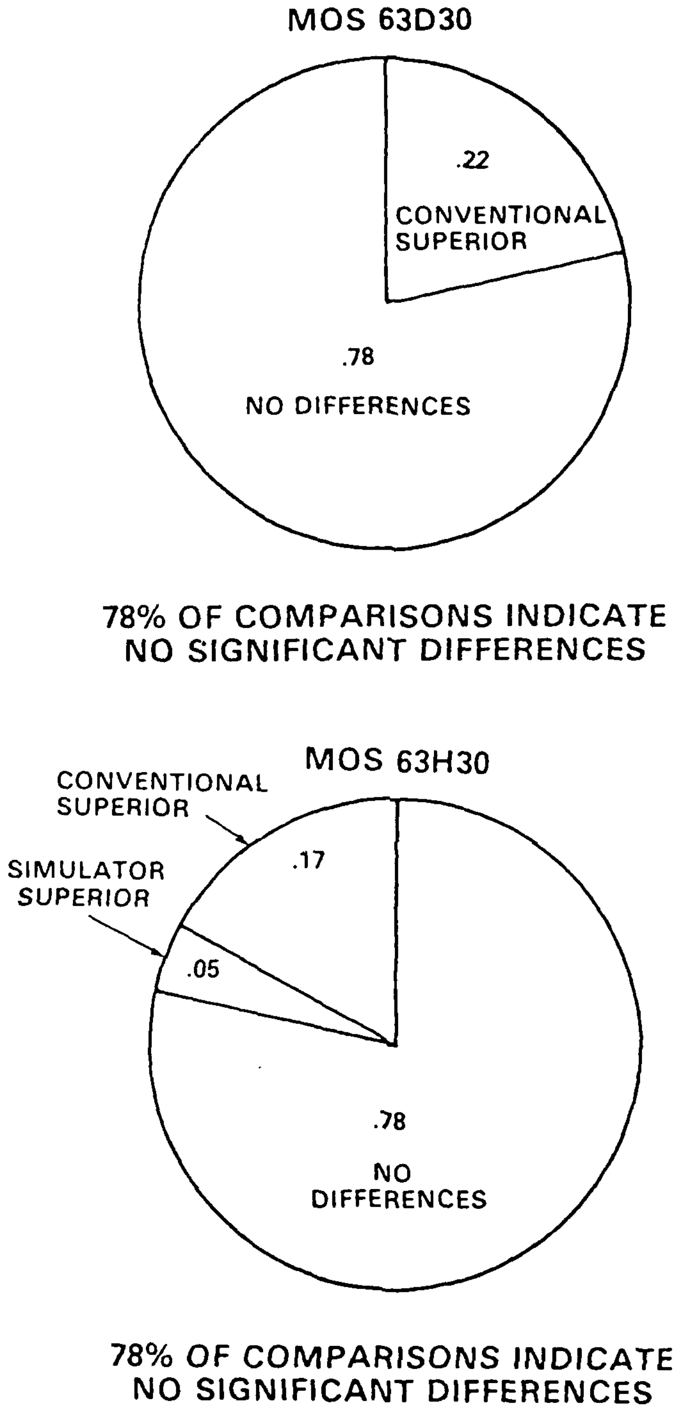

Figure 3. Summary of comparisons of conventional training to training with the Grumman device, Aberdeen Proving Ground, Maryland.

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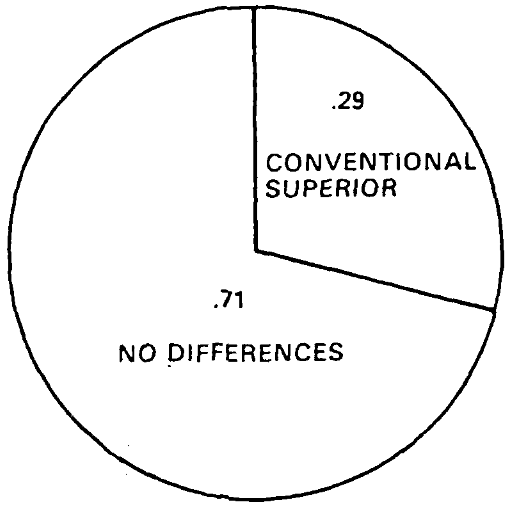
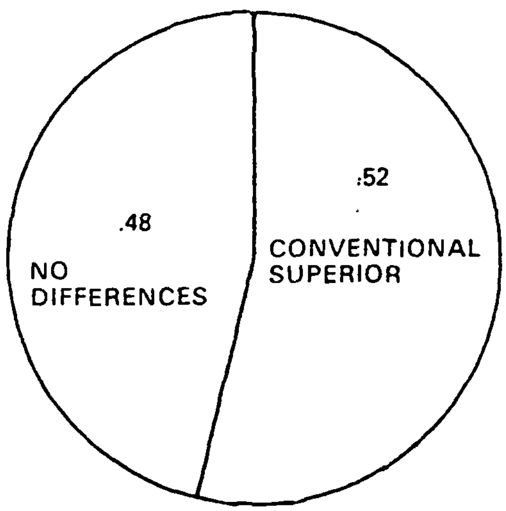


71% OF COMPARISONS INDICATE
NO SIGNIFICANT DIFFERENCES

MOS 63W10



48% OF COMPARISONS INDICATE
NO SIGNIFICANT DIFFERENCES

Figure 2. Summary of comparisons of conventional training to training with the Seville/Burtek device, Aberdeen Proving Ground, Maryland.

evaluation provides expert opinion data on device features and the procedures used in AMTESS device development.

AMTESS Field Evaluations. Trainees were taught either conventionally or on an AMTESS device and their performance was tested with hands-on exercises on operational equipment. Since the standard school performance tests generate gross overall indices of trainers performance and a more detailed evaluation was required, new performance tests were developed. These tests consisted of detailed step by step measures of performance on selected criterion tasks. The performance of the trainees was evaluated in terms of time, accuracy, and required instructor interventions.

The Seville/Burtek device, in its automotive configuration, was tested in two MOSs: 63B30 (Organizational Maintenance Supervisor)and 63W10 (Direct Support Vehicle Repairman). Its electronics version, was tested in MOS 24C10 (Hawk Missile Firing Section Mechanic). The Grumman device, in its automotive configuration was also tested in two MOSs: 63D30 (Self-propelled Field Artillery Mechanic) and 63H30 (Direct Support Maintenance Supervisor). The Grumman electronics configuration was tested in MOS 24C10 (Hawk Missile Firing Section Mechanic). However, the Grumman electronic configuration was not compatible with conventional training and therefore, it was not possible to obtain a comparison group. Only the performance of students trained on the Grumman AMTESS electronics device was assessed without comparison to a conventional training group.

Generally, the performance of AMTESS trained and conventionally trained students was equivalent. All students passed the schools' criteria for successful accomplishment of the tasks trained during the evaluation. Where differences did exist, in general the conventionally trained group was superior. Most of these differences were in the time to complete the criterion task and in the number of instructor interventions required for the trainee to complete the task. In most cases, however, the AMTESS trained students could perform the task but required some additional orientation on the operational equipment since the AMTESS devices often did not contain critical components normally found on the operational equipment.

Figure 2 is a summary of all comparisons on the three dependent measures at Aberdeen Proving Ground between groups trained on the Seville/Burtek device and groups trained conventionally. In MOS 63W10, an entry level MOS, 52% of comparisons showed conventional training superior to AMTESS training. This figure drops to only 29%,however, in MOS 63B30, a higher skill level MOS. Apparently, trainees with more experience on the operational equipment do not require as much operational equipment orientation after AMTESS training as do entry level trainees.

A similar summary of all comparisons of the Grumman device and conventionally trained groups in the automotive area is provided in Figure 3. Here we see that in both MOS 63D30 and 63H30 almost 80% of the comparisons showed no differences between training conditions. As with the Seville Burtek device, differences that were found consisted of time delays and increased frequency of instructor interventions for the Grumman trained group. Overall ability to correctly complete the criterion tasks did not differ between training conditions.

The AMTESS program seeks to develop and test a model for generic maintenance simulation training systems. The model consists of two components: The core component and a task specific 3D modular component. The core component controls the device and includes a general purpose micro processor, a 2D visual display interface, and an instructor station. The 3D modular component consists of either a simulation of a complete unit (e.g., an engine) or simulations of component units (e.g., battery, starter motor). Table 1 is a summary of the designs of two AMTESS breadboard devices that were evaluated at Army Schools. A breadboard device is an early engineering development tool which allows formative evaluations of design concepts prior to the prototype phase. One AMTESS breadboard device was developed by a consortium of Seville Research and Burtek, Inc. and the other was developed by Grumman Aerospace. Both versions followed the general AMTESS model described above. The versions differed in their microprocessors, their 2D instructional delivery systems, the tasks they were designed to train and their instructional philosophies. Each AMTESS breadboard device was built with two 3D modules: one module to train automotive maintenance tasks and one to train electronics maintenance tasks. The automotive versions were evaluated at the Army Ordnance Center and School at Aberdeen Proving Ground, Maryland and the electronics versions were evaluated at the Army Air Defense School at Fort Bliss, Texas.

Table 1

AMTESS Breadboards

Seville/Burtek	Grumman
Microprocessor (LSI-11, 16 bit)	Microprocessor (M68000, 16 Bit)
CRT (TECT) and Response Panel	Color CRT with Touch Screen (Text)
Rear-Projection (35mm Slides)	Color CRT Pictures (from Video Disc)
Diesel Engine Mock-Up	Engine Components
Instructor Station	Instructor Station

Field Research

The field research described below consisted of training effectiveness evaluations of the AMTESS breadboard devices and analytical evaluations of the AMTESS program. Because of differences in device designs and programs of instruction, we could not directly compare the training effectiveness of the breadboards. Instead, the training effectiveness of each device was compared to that of conventional training (classroom instruction supplemented by hands on practice with operational equipment). The analytical is reported in the literature is applied research. This means that the information is usually based on the comparison of entire devices to actual equipment rather than the investigation of specific features. Therefore, the development and use of this prototype decision support system is focusing the exisitng empirically based knowledge of training device configuration for efficient use. This focusing identifies gaps in what is known about the complex factor relationships in training device design and use. Obviously research is needed to close the gaps in existing knowledge and also improve the decision support system. We anticipate a productive cycle of organizing and using empirical information to improve the decision support system, and identifying fruitful areas for research through our efforts to improve and extend the system.

Summary of Handling Empirical Data and Delivering Empirically Based Decision Support

Our goal is to provide decision support to the Army in developing and procuring cost effective and training efficient simulators and training devices. We hope that by providing empirically based decision support for training device specification and use, we will also improve Army training. We believe that identifying what is known and what is not will also improve our research efforts in training device design and use. In addition we hope to be able to integrate the information and decision support that this system will be able to provide with the other automated systems (Man Integrated Systems Technology, Weddle, 1983; Early Training Estimation System, O'Brien & Livingstone, 1980) that are being devised to support the Life Cycle System Management Model (see Rhode, Skinner, Mullin, Friedman, Frances, & Carroll, 1980 or Kane & Holman, 1982, for review) which is used by the Army to manage acquisition and use of training equipment. The previous section has described our efforts to organize training system and training device factors and to use this organization to develop a data base on training device information. It also discussed plans to apply three techniques to effectively use the information contained in the data base: meta-analysis, delphi analysis, and structured interviews. Finally, plans for delivering this information to the user through a decision support system using expert system techniques were discussed.

Conclusion

This presentation has described two thrusts of our training device research program. The first thrust is to develop empirical data on training device design and use. The second thrust is to organize these data in a manner that will provide useful information and guidance to the Army training community. The data generation effort began in support of the PM TRADE AMTESS effort. Some valuable data have been developed through the field evaluations and the analytical evaluations of the AMTESS project. We anticipate a series of experiments using the AMTESS devices to address fundamental questions about a wide range of training system variables. In addition, the basic research program on simulator fidelity will provide data on a wide range of fidelity effects and interactions. These efforts and other research efforts reported in the literature will provide an empirical base for guidance and decision support.

The data handling and delivery of decision support efforts are already showing positive benefits by providing guidance to the data generation research efforts. The organization of empirical information should help organize the entire field of training device research, by providing researchers with a solid compendium of the research conducted over the last thirty years. The development of a data base and the application of analysis techniques futher contribute to the organization of knowledge to support both future research and current decision support system development efforts. The use of computer technology in developing a training device decision support system has as a partial product the advancement of computer applications technology. More importantly, a training device decision support system thoroughly based in empirical data will provide an easily useable and efficient source of information and guidance to the Army training community.

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Appendix

General Information about Training Devices and Features

Typical Features of Simulators and Training Devices

Fidelity - There are many ways to talk about how the training equipment approximates the actual equipment, system or environment that is being modeled for investigation or training. The term fidelity (which some people will not use) can be used to describe the trainee's perceptions of the equipment, or it can be used solely to describe the actual characteristics of the training equipment, or it can be used in several other ways.

The US Army currently evaluates training devices and simulators along two fidelity dimensions: physical and functional (see TRADOC Training Device Requirements Document Guide, 1979). Physical fidelity refers to the degree to which the training device or simulator matches the actual equipment. Functional fidelity refers to the degree to which the training device or simulator matches the operations that are possible and the information presented in the operation of the actual equipment.

The features which are added onto the training device or simulator can thus degrade the fidelity while enhancing the effectiveness or efficiency of training. Of course, the degree of fidelity can also be lowered simply because a high level is not required for training in some particular situation. The appropriate level of fidelity or actual equipment representation is thus dependent on the type of task being trained, the proficiency level desired as an outcome of the training, the type of overall training program being used, and the necessary adjunct training features of the training device or simulator.

TRAINING TYPES

INDOCTRINATION - occurs early in learning process (ideally), covers what the task is and how (in general) the task is performed

PROCEDURAL - provides essential nomenclature and sequencing knowledge for task elements

FAMILIARIZATION - allows initial practice of task procedures and initial learning of task/skill dynamics.

SKILL - allows practice toward developing proficiency in the task.

TRANSITION - practice that allows adaptation of previously acquired skills on differing equipment to the new target equipment or task

CRISIS - training aimed at ensuring optimal responses in minimal or adequate time under stressful conditions.

ADJUNCT FEATURES

Freeze Capability. Under certain conditions such as trainee error, the device can freeze an instructional sequence. This allows evaluation and discussion of the action sequence "on the fly" so that sub-optimal action patterns can be eliminated.

Restart/Resequence Capability. The capability to restart an instructional sequence at any point. This allows a whole-task trainer to be a part-task or partial sequence trainer as well.

Malfunction Selection. Provides simulated malfunctions chosen by the instructor. This allows training and practice on the higher level problem solving tasks associated with repair. At the most complex, the system may incorporate multiple faults and reflect repair errors made during training.

Sign-in Capability. Trainee can sign into the device at any authorized time after providing specified information (passwords, etc.) to the device. This is a valuable feature for individual record keeping or self-paced instruction when the training device is required to maintain trainee records.

Number/Quality of Responses. The device can record, save, and display both the quality and quantity of trainee responses. This can be a single session system that does not maintain records between training sessions, or it can be a full computer-based tracking system that maintains total training program records.

Internal Monitoring of Instructional Features. The device can monitor specified variables and/or responses for specific actions (e.g., device freezes if designated monitor reads in upper half of scale or device begins providing altered feedback if a designated control is activated). This feature can be used in conjunction with computer-based instruction to control or branch to different training problem presentations.

Augmented Feedback. Under specific conditions or schedules, the device can enhance the feedback received by the trainee. For example, if the information that is used to stop, start, or maintain and adjust something during a task is difficult to detect or observe, then this information is made more noticable in some way.

Supplemental Information. In some instances, the normal information that is used to guide a behavior cannot be altered, and therefore some additional information is used to ease training by emphasizing the information content in the task.

Next Activity Features. Introduction of the next activity or lesson can be linked to specific trainee actions by the instructor. This is similar to the branching activities used in computer-based training.

Stimulus Instructional Features. The instructor/course developer can specify the rates and characteristics of stimuli presented to the trainee. This is basically a lower level method for enhancing feedback or providing supplemental information. Often by eliminating some stimuli, the salience or importance of other stimuli is made more obvious. An example would be to turn off or shut down irrelevant portions of the training device during certain training sequences.

Automated Demonstration. The capability to develop and present preprogrammed scenarios for trainee observation and instruction can provide the trainee with a model of expected performance or a demonstration of the consequences of some critical action.

Record/Playback. A demonstration technique that may be used to record and later replay some portion of trainee's behavior during the training session. This can be used to review critical errors or review and reward good performance, as well as develop automated demonstrations.

Adaptive Syllabus. Techniques for computer control of trainee progression based upon trainee's performance. The training scenario is varied as performance changes, presenting the trainee with new knowledge and new tasks as the old material is mastered to some criteria. The most complete level of computer-based instruction also allows for a lesson authoring system.

Lesson Authoring System. Capability that allows for the instructor to prepare lesson scenarios or change malfunction and response patterns in the training program sequence.

Record Keeping and Processing. Ability to collect long-term performance data on trainee and do simple individual, group, class analysis of performance and develop ratings of progress through the training program.